Opportunities with BioEnergy

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Presentation Overview

- Feedstocks
- Conversion technologies
- End uses

The Bioenergy Value-Added Chain

End Use

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Conversion

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Feedstocks

Biomass Feedstocks

- Crop harvesting and processing residues
- Animal manures
- Energy crops (agr & forestry)
- Food processing wastes
- MSW and urban wood wastes

Biomass Feedstocks

- Stored solar energy
- Needs definition
- Great variety
- Great flexibility
- The only *renewable* source of liquid fuels

Energy Crops

- Semi-tropical climates
  - Eucalyptus in Florida
    - 30 dt/acre/yr
  - Leucaena in Florida
    - 20 dt/acre/yr
- Temperate climates
  - 6 dt/acre/yr

Energy Crops

- Needed for high yields
  - Good soil
  - Good climate
  - Water
  - Fertilizer
- Animal manures

Handling: From the Field to the Conversion Device

- Harvesting
- Drying
- Storage
- Transportation
- Grinding

Conversion Pathways

- Biological
- Thermochemical
- Chemical
- Mechanical

Conversion Technologies

- Chemical
  - Biodiesel
- Mechanical
  - Pellets
  - Cubes

Conversion Technologies: Biological

- **Biological**

Feedstock → Microbes → Products

- **Examples**
  - **Anaerobic digestion (biogas)**
    - **Landfill gas**
    - **Wastewater treatment plants**
    - **Animal manure digesters**
  - **Ethanol fermentation**

Conversion Technologies: Thermochemical

- **Types**
  - **Direct combustion**
  - **Gasification**
  - **Pyrolysis/liquefaction**
- **Characteristics**
  - **Fast reaction times**
  - **Smaller systems**

Basic Combustion Stages

INCREASING TEMPERATURE

(> 500 F) Oxidation of char, ash remains

(400 – 500 F) all gases and volatiles driven off, char remains

(290 – 400 F) decomposition accelerates

(270 – 290 F) Ignition, further decomposition

(220 – 270 F) Decomposition starts, gases and vapors given off

(<220 F) Drying

Unlimited oxygen

Thermal Gasification

INCREASING TEMPERATURE

(> 500 F) Oxidation of char, ash remains

(400 – 500 F) all gases and volatiles driven off, char remains

Syngas piped from process

(290 – 400 F) controlled decomposition

Oxygen limited or absent

(270 – 290 F) Ignition, further decomposition

(220 – 270 F) Decomposition starts, gases and vapors given off

(<220 F) Drying

Charcoal Production

INCREASING TEMPERATURE

Char remains

All Oxygen cut off

(400 – 500 F) all gases and volatiles driven off, char remains

(290 – 400 F) controlled decomposition

Oxygen supply limited

(270 – 290 F) Ignition, further decomposition

(220 – 270 F) Decomposition starts, gases and vapors given off

(<220 F) Drying

BioOil Production

INCREASING TEMPERATURE

Oxidation of char, ash remains

All gases and volatiles driven off, char remains

Combustible Gas

Syngas VAPORS condensed

BioOil

(290 – 400 F) controlled decomposition

No oxygen present

(270 – 290 F) Ignition, further decomposition

(220 – 270 F) Decomposition starts, gases and vapors given off

(<220 F) Drying

Process Comparisons

	Product Yield			Process Conditions	
Process	**LIQ, %**	**CHAR %**	**GAS, %**	**TEMP**	**RES. TIME**
Fast pyrolysis	**75**	**12**	**13**	**Mod**	**Short**
Carbonization	**30**	**35**	**35**	**Low**	**Long**
Gasification	**5**	**10**	**85**	**High**	**Long**

Source:NREL

Energy Applications

- Electricity generation
- Space heating and cooling
- Transportation
- Process heat

Utility Fuel Cost Comparison

- Typical utility fuel costs
  - $1.25-1.75/MBtu, delivered
- Assume 16.5 MBtu/dry ton of biomass
- $1.25/MBtu = ~ $20/dry ton of biomass

Levelized Costs, cents/kWh

- 2.4 - 6.3 Landfill gas
- 3.5 - 15.3 Municipal solid waste
- 3.9 - 4.4 Natural gas CC
- 5.2 - 5.5 500 MW pulverized coal
- 6.3 - 11.0 Biomass (direct combustion)
- 19.4 - 47 Solar photovoltaic

Utility Policy

- Green Power
  - 1.5 cents/kWh premium
- Federal tax credit
  - 1.5 cents/kWh
- Renewable Portfolio Standard
  - Require a minimum percentage from renewables

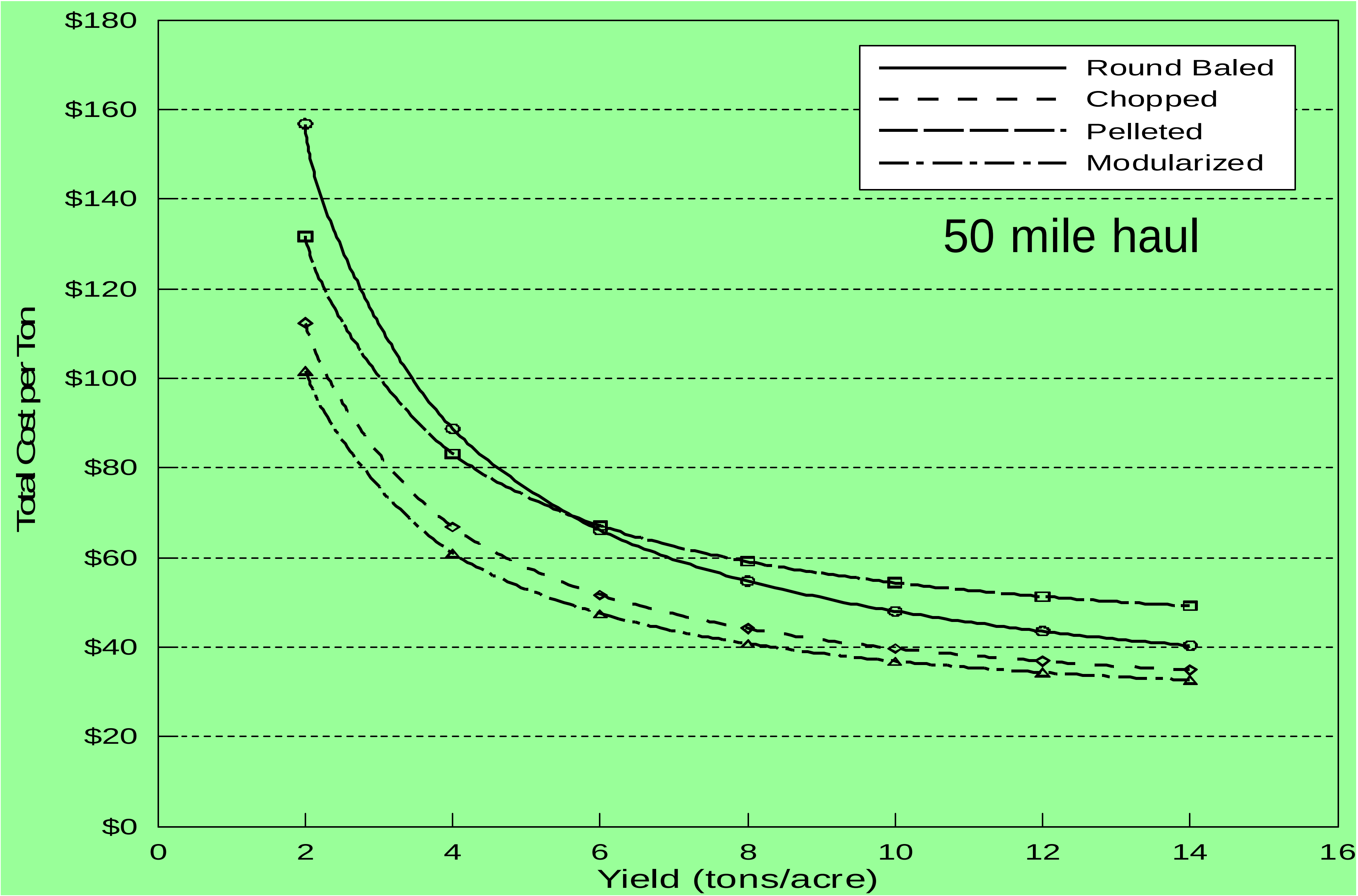
Utility: Cofiring

- Uses existing infrastructure
- Low cost method of utilization
- PC boilers, same feed system
  - Capital cost: $50-100/kW
  - 2% Btu basis maximum
- PC boilers, separate feed systems
  - Capital cost: $500/kW
  - 5% Btu basis maximum

Alabama Switchgrass Cofiring

- Based on 300 acres of switchgrass at Lincoln, AL
- Pilot testing at SRI in Birmingham, AL
- Full scale testing at Plant Gadsden, Gadsden, AL

Switchgrass Delivered Costs



Alabama Switchgrass Cofiring

Material handling problems

- Transportation costs
- Feeding into boiler
- Storage of bales

Liquid Fuels

- Ethanol
  - Sugar
  - Starch
  - Cellulose
- Biodiesel
  - Vegetable oils
  - Waste greases, oils, and fats
- BioOils
  - Virtually anything

Comparison: Corn to Wood

- Corn Grain

$$\frac{\$2.00 \text{ / bushel}}{2.5 \text{ gal / bushel}} = \$0.80 \text{ / gal}$$

- Waste Wood

$$\frac{\$16.00 \text{ / ton}}{80 \text{ gal / ton}} = \$0.20 \text{ / gal}$$

Ethanol-from-Cellulose Processes

- Biological fermentation pathways
  - Acid hydrolysis
  - Enzymatic hydrolysis
- Thermochemical pathway
  - Gasification with catalytic conversion
- Hybrid pathway
  - Gasification with biological fermentation

BioOil Advantages

Direct combustion or gasification systems:

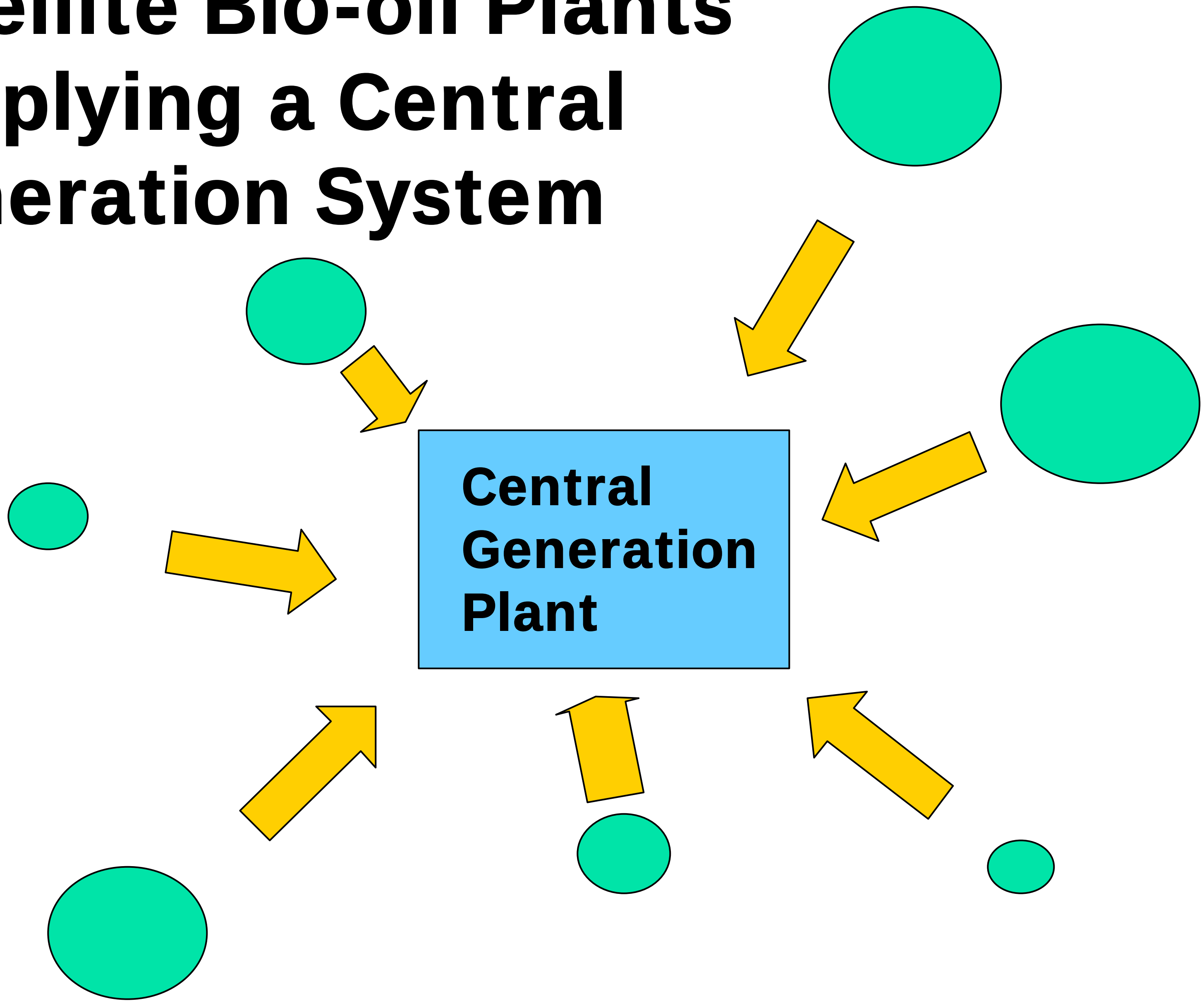
- Must be close coupled to end use
- Must be able to follow energy demand
- Requires transportation of raw materials to the plant

Energy Density Comparisons

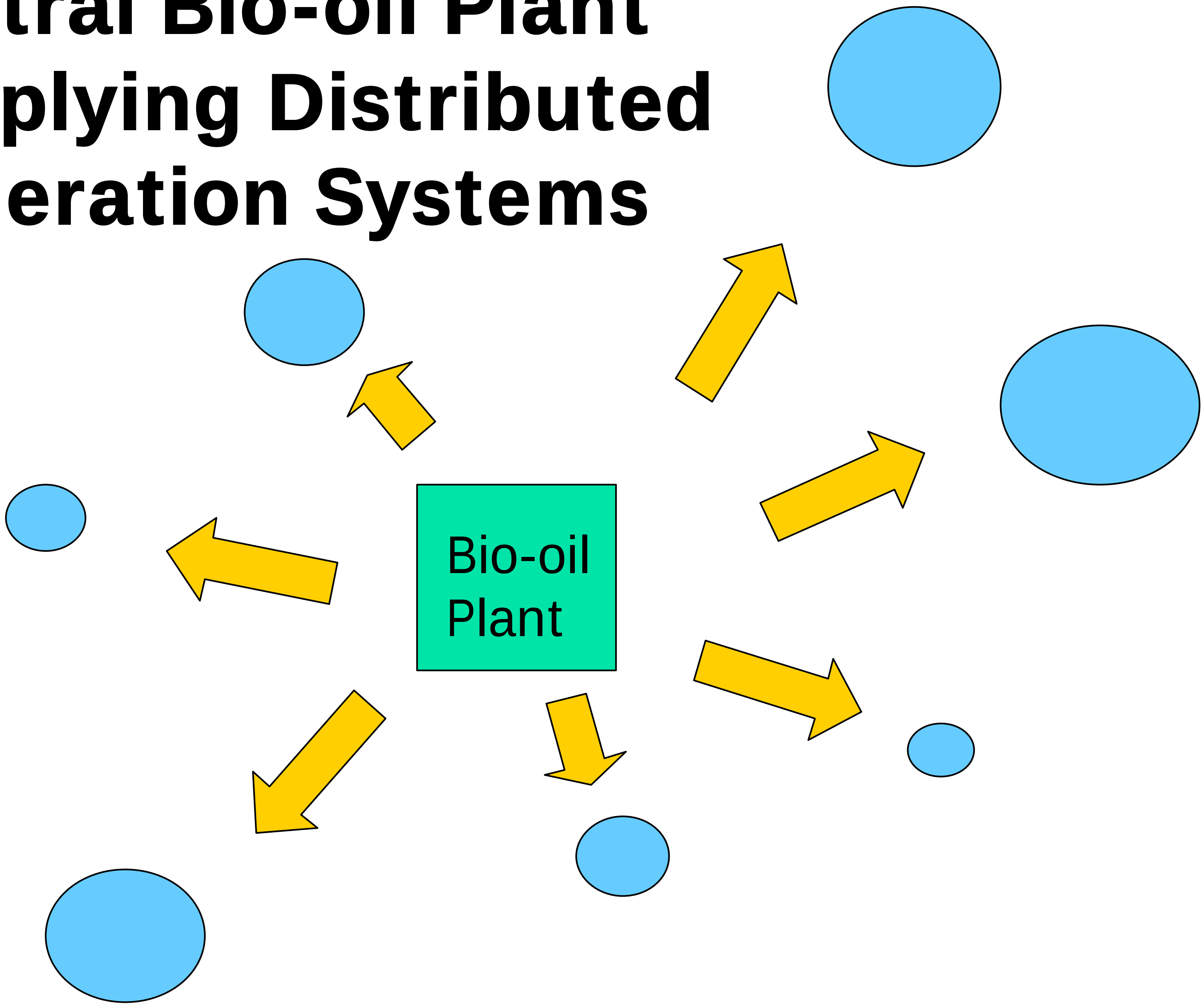
	lb/cf	Btu/lb	Btu/cf	Ratio	Ratio
Bales, grass	12	7,100	85,200	1.0	
Green wood chips	22	4,546	100,012	1.2	1.0
Poultry litter	20	6,000	120,000	1.4	1.2
Cubes, grass	30	7,600	228,000	2.7	2.3
Pellets, wood or grass	40	7,500	300,000	3.5	3.0
BioOil	75	8,000	600,000	7.0	6.0

Plus ease of handling, transportation, and storage of BioOils

Satellite Bio-oil Plants Supplying a Central Generation System



Central Bio-oil Plant Supplying Distributed Generation Systems



Animal Manure Management: Application to the Industry

- Thermochemical processes can provide thermal and electrical energy (CHP)
- Concentrates the nutrients in the ash
- Can be used to provide energy for feed or meat processing

Biorefineries

- All operations in one building
- Utilizes whole plant
- “Fractionates” plant to recover highest value products
- Minimizes processing residues
- Maximizes revenues

Summary

- Great diversity of feedstocks
- Great diversity of conversion options
- Great diversity of end-use options
- “Growing” opportunities